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MEASURES TO STRENGTHEN INTERNATIONAL CO-OPERATION IN NUCLEAR, RADIATION AND WASTE SAFETY

(c) STUDY OF THE RADIOLOGICAL SITUATION AT THE ATOLLS OF MURUROA AND FANGATAUFA

1. On 22 September 1995, in resolution GC(39)/RES/23 entitled "Nuclear testing", the General Conference, inter alia, called on all States concerned "*to fulfil their responsibilities to ensure that sites where nuclear tests have been conducted are monitored scrupulously and to take appropriate steps to avoid adverse impacts on health, safety and the environment as a consequence of such nuclear testing*".

2. On 18 March 1996, the Director General informed the Board that:

> "..... *the Secretariat had been requested by the Government of France to conduct a study designed to assess the radiological situation at the atolls of Mururoa and Fangataufa in French Polynesia.* ..... *An International Advisory Committee to supervise the study was being established under the chairmanship of Dr. Gail de Planque of the United States.*"

3. On 14 April 1996, the Secretariat embarked upon the Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa as an extrabudgetary task.[1] The Government of France covered most of the direct costs of the Study and provided invaluable logistic assistance throughout. Significant in-kind contributions were made by Argentina, Australia, Austria, Belarus, Belgium, Cuba, Denmark, Fiji, Germany, Indonesia, Japan, the Republic of Korea, New Zealand, Norway, the Russian Federation, Slovenia, Spain, Sweden,

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[1] Task 6 ("To complete the assessment of the current and predicted radiological situation of the Mururoa and Fangataufa Atolls") under "Tasks planned for 1997-98" within the framework of Project I.4.02 ("Assessment of Radiological Situations") of Subprogramme I.4 ("Radiation Assessments and Emergencies") of Programme I ("Radiation Safety") in the Agency's Programme and Budget for 1997 and 1998 (document GC(40)/10). See page 269 of Part II - Management Part - of document GC(40)/10. See also paragraph I/6 of the Agency's Budget for 1998 (document GC(41)/10).

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Switzerland, the United Kingdom, the United States of America, the European Commission, the South Pacific Forum, the South Pacific Regional Environment Programme, the Office of the Sub-Regional Representative for the Pacific of the Food and Agriculture Organization of the United Nations, the World Health Organization and the United Nations Scientific Committee on the Effects of Atomic Radiation. In addition, significant in-kind contributions were made by the laboratories and other institutions involved in the Study, whose activities were co-ordinated by the Agency's Laboratories at Seibersdorf, Austria, and the IAEA Marine Environment Laboratory, Monaco. The laboratories and other institutions were: the Australian Nuclear Science and Technology Organisation (ANSTO), Sydney, and the Australian Radiation Laboratory, Melbourne, Australia; the Institut für Anorganische Chemie, University of Vienna, and the Federal Institute for Food Control and Research, Vienna, Austria; the Institute of Radiobiology, Minsk, Belarus; the Centro de Isótopos, Havana, Cuba; Risø National Laboratory, Roskilde, Denmark; the Physikalisch-Technische Bundesanstalt, Braunschweig, and the Federal Fisheries Research Centre, Hamburg, Germany; the National Radiation Laboratory, Christchurch, and the Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand; the Norwegian Radiation Protection Authority, Østeras, Norway; the Jožef Stefan Institute, Slovenia; the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (C.I.E.M.A.T.), Madrid, Spain; the Radiochemistry Group, Central Veterinary Laboratory, Addlestone, Surrey, and the Centre for Environment, Fisheries and Aquaculture Science, United Kingdom; and the US Department of Energy's Environmental Measurements Laboratory, New York, and Lawrence Livermore National Laboratory, Livermore, California, United States.

4. The Secretariat kept Member States informed about the Study through documents GC(40)/INF/4 and GOV/INF/815-GC(41)/INF/6.

5. On 16 March 1998, the Director General informed the Board that:

> *"[t]he Study was now essentially complete, and publication of the Study Report was scheduled for May 1998."*

6. The reports on the Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa, which are being issued by the IAEA in its Radiological Assessment Reports Series, are: a ***Main Report***, which incorporates an *Executive Summary*; a ***Technical Report*** in six volumes (*"Radionuclide Concentrations Measured in the Terrestrial Environment of the Atolls", "Radionuclide Concentrations Measured in the Aquatic Environment of the Atolls", "Inventory of Radionuclides Underground at the Atolls", "Releases to the Biosphere of Radionuclides from Underground Nuclear Weapon Tests at the Atolls", "Transport of Radioactive Material within the Marine Environment", and "Doses due to Radioactive Materials Present in the Environment or Released from the Atolls"*); and a ***Summary Report*** for the benefit - in particular - of persons with executive, managerial and administrative

responsibilities.[2] The *Executive Summary* of the *Main Report* is attached hereto (Attachment 1).

7. In May 1998, the Agency sent a small team - including the Chairman of the International Advisory Committee, the Chairmen of the two Task Groups involved in the Study, and a representative of the Project Management Office established by the Agency's Secretariat for the Study - to the South Pacific region in order to present the results of the Study to representatives of the governments of member States of the South Pacific Forum[3] and representatives of French Polynesia.

8. On 11 June 1998, the Board had before it a document GOV/1998/14 briefly recapitulating the history of the Study and containing the *Executive Summary* of the *Main Report*. It expressed its appreciation to the members of the International Advisory Committee and authorized the transmission of the document's contents to the General Conference. The summary record of the Board's discussion regarding the Study is attached hereto (Attachment 2).

9. From 30 June to 3 July 1998, the Agency hosted in Vienna an International Conference on the Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa,[4] the main purpose of the Conference being to facilitate discussion of the results of the Study by the scientific community and other interested parties. The Conference was attended by 93 representatives of 36 Member States and 5 international and regional organizations, and 5 observers. The Conference's "Conclusions and Closing Remarks" are attached hereto (Attachment 3).

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2 The IAEA also issued a public information booklet relating to the Study.

3 The member States of the South Pacific Forum are: Australia, the Cook Islands, Fiji, Kiribati, the Marshall Islands, Micronesia, Nauru. New Zealand, Niue, Palau, Papua New Guinea, the Solomon Islands, Tonga, Tuvalu, Vanuatu and Western Samoa.

4 See Annex III ("Conferences, Symposia and Seminars in 1998") to the Agency's Budget for 1998 (document GC(41)/10).

STUDY OF THE RADIOLOGICAL SITUATION AT THE ATOLLS OF MURUROA AND FANGATAUFA

EXECUTIVE SUMMARY

INTRODUCTION

(1) In April 1996, following a request from the Government of France, the International Atomic Energy Agency (IAEA) embarked on a *Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa*, in French Polynesia, where France conducted 193 *expériences nucléaires* (nuclear experiments) above and beneath the atolls between July 1966 and January 1996.

(2) Mururoa and Fangataufa Atolls are situated at 21° 50′ S, 138° 54′ W and 22° 14′ S, 138° 45′ W, respectively, in the middle of the South Pacific Ocean, halfway between Australia and South America; they belong to the Pitcairn-Gambier island chain at the south-eastern extremity of the Tuamotu archipelago. An atoll is a ring-shaped coral reef enclosing a lagoon. The reef is a narrow rim - jutting a few metres at most above the surrounding ocean - which may be cut in many places by irregular channels, termed *hoas*, with the resulting formation of a string of islets, termed *motus*. Mururoa and Fangataufa Atolls have evolved from extinct submarine volcanoes, and each rests upon a massive volcanic substratum capped by a coral reef platform and surrounded by ocean water thousands of metres deep. Therefore, in vertical structure each atoll consists essentially of two rock sequences: an igneous volcanic *basalt basement* and, capping it, sedimentary *carbonate formations* hundreds of metres thick.[1] The carbonate formations are heterogeneous and fairly porous and the basalt basements are of lower permeability, but all are saturated with sea water. There is slow migration of water from the ocean inwards, rising through the basalt basements and carbonate formations towards the lagoons.

(3) The *expériences nucléaires* were of two types: 178 were *nuclear tests*, in which nuclear devices were exploded with large releases of fission energy, and 15 were *safety trials*, in which more or less fully developed nuclear devices were subjected to simulated accident conditions and the nuclear weapon cores were destroyed by means of conventional explosives, with no or - on a few occasions - very small releases of fission energy. Forty-one of the nuclear tests were *atmospheric nuclear tests* which took place - 37 at Mururoa Atoll and 4 at Fangataufa Atoll - between July 1966 and September 1974, and 137 were *underground nuclear tests* which took place - 127 at Mururoa Atoll and 10 at Fangataufa

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[1] Each coral reef platform consists of carbonate rocks of organic origin - limestones and dolomites. For the purposes of the Study, the classification of the carbonate rocks is not important and they will therefore be simply referred to as *carbonate formations*.

Atoll - between June 1975 and January 1996. Of the 15 safety trials, all of which were carried out at Mururoa Atoll, 5 were *atmospheric safety trials* and 10 were *underground safety trials*. Three underground safety trials had small releases of fission energy associated with them.

(4) The *expériences nucléaires* were carried out as follows:

- Most of the atmospheric nuclear tests were carried out with the device suspended from a balloon some hundreds of metres above the surface of the lagoons; in three cases, the devices were dropped from aircraft. In all cases the detonation altitude was sufficient for the fireball not to reach sea level, thereby minimizing the production of local fallout. There were, however, four atmospheric nuclear tests - three at Mururoa Atoll and one at Fangataufa Atoll - in which the device was mounted on a barge floating in the lagoon; most of the residual radioactive material presently in the accessible environment of the atolls was produced by these nuclear tests. The five atmospheric safety trials were conducted on the northern part of Mururoa Atoll, on three motus: *Colette, Ariel* and *Vesta.*

- The underground nuclear tests were conducted in the basalt basement at depths between about 500 m and 1100 m, in shafts drilled vertically beneath the rims or the lagoons. Each explosion generated intense heat and high pressures, melting the basalt rock in the immediate vicinity of the detonation point and forming a roughly spherical *cavity* and a lens-shaped pool – or "*meniscus*" – of molten basalt rock at the bottom of the cavity. Upon cooling, the molten basalt rock solidified as a glass-like lava. Several hours after the explosion, the fractured basalt rock above the cavity collapsed, creating a *cavity-"chimney"*[2] filled with rubble. The cavity-chimney eventually filled with water infiltrating from the surrounding basalt rock. Much of the residual radioactive material associated with the underground nuclear test was trapped in the lava, but some radionuclides were deposited on the rubble and are available for exchange with water in the cavity-chimney. The ten underground safety trials were carried out in shafts drilled vertically beneath the rim on the north-eastern part of Mururoa Atoll. Seven of the underground safety trials were carried out in the carbonate formations, at depths in excess of 280 m, and three were carried out in the basalt basement. The three underground safety trials which involved some fission energy release took place in the carbonate formations.

The French programme of *expériences nucléaires* ceased on 27 January 1996.

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2 The term (cavity-) "*chimney*" has been used extensively in the United States literature to refer to the rubble cone formed after the collapse of the cavity formed by an underground nuclear test. Although the term is incorrect, as it evokes the idea of a duct leading to the free atmosphere rather than a closed cavity, it has become common jargon in the technical literature and was used throughout the reports resulting from the Study.

OBJECTIVE

(5) The Study was designed to assess the residual radiological conditions at the atolls after the end of all the *expériences nucléaires* and covered both the present radiological situation and the potential long-term radiological situation. Specifically, the aims of the Study were as follows:

- to assess the situation at the two atolls and in involved areas from the point of view of radiological safety;
- to ascertain whether there are any radiological hazards to people; and
- to make recommendations on the form, scale and duration of any remedial action, monitoring or other follow-up action that might be required.

The Study was therefore prospective in nature. Nevertheless, it took note of and summarized the extensive retrospective radiological assessments of the nuclear tests which have been carried out over the years by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

FRAMEWORK

(6) The Study used as its principal international authority on radiation protection matters the *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*, which are jointly sponsored by the Food and Agriculture Organization of the United Nations (FAO), the IAEA, the International Labour Organisation, the Nuclear Energy Agency of the Organization for Economic Co-operation and Development, the Pan American Health Organization and the World Health Organization (WHO) and were published by the IAEA in 1996 (Safety Series No.115).

ORGANIZATION AND SUPPORT

(7) The organizational basis for the Study consisted of: an International Advisory Committee (IAC); two task groups and five working groups set up by the IAC[3]; a Project Management Office set up by the IAEA; and a Liaison Office set up by the French Government (see the following diagram and the annexed List of Participants). The first

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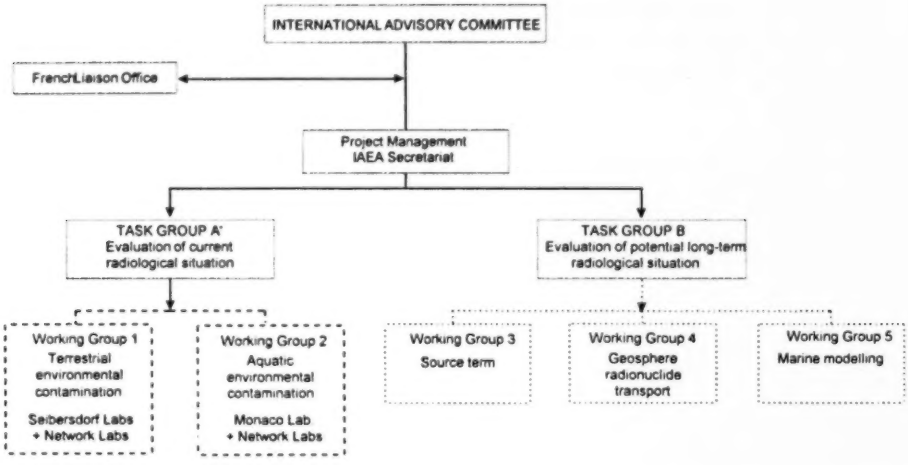
3 The IAC was chaired by Dr. E. Gail de Planque of the United States of America and comprised ten prominent scientists from ten IAEA Member States plus experts representing *ex officio* WHO, UNSCEAR, the South Pacific Forum and the European Commission.

meeting of the IAC took place in Vienna on 13 and 14 April 1996, marking the commencement of the Study.[4]



* The Working Groups of Task Group A were supported by a network of laboratories and other institutions co-ordinated by the IAEA's Laboratories at Seibersdorf, Austria, and another co-ordinated by the IAEA Marine Environment Laboratory, Monaco. The network of laboratories and other institutions co-ordinated by the IAEA's Laboratories at Seibersdorf, Austria, consisted of the Institut fur Anorganische Chemie and the Federal Institute for Food Control and Research, Vienna, Austria; the Institute of Radiobiology, Minsk, Belarus; the Centro de Isotopos, Havana, Cuba; the Physikalisch-Technische Bundesanstalt, Braunschweig, Germany; the Norwegian Radiation Protection Authority, Østeras, Norway; the Jožef Stefan Institute, Ljubljana, Slovenia; the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (C I E M A T), Madrid, Spain; the Radiochemistry Group, Central Veterinary Laboratory, Addlestone, Surrey, United Kingdom; and the US Department of Energy's Environmental Measurements Laboratory, New York, United States. The network of laboratories and other institutions co-ordinated by the IAEA Marine Environment Laboratory, Monaco, consisted of the Australian Nuclear Science and Technology Organisation (ANSTO), Sydney, and the Australian Radiation Laboratory, Melbourne, Australia; Risø National Laboratory, Roskilde, Denmark; the Federal Fisheries Research Centre, Hamburg, Germany; the National Radiation Laboratory, Christchurch, and the Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand; the Centre for Environment, Fisheries and Aquaculture Science, United Kingdom; and Lawrence Livermore National Laboratory, Livermore, California, United States.

CONDUCT OF THE STUDY

General approach

(8) The Study activities were divided between two Task Groups (see the above diagram):

- Task Group A (supported by the "Terrestrial environmental contamination" and "Aquatic environmental contamination" Working Groups) evaluated the current levels of residual radioactive material in the environment of the atolls and their surrounding waters and assessed the present and future radiation doses attributable to this residual radioactive material. Using the information provided by Task Group B, it also assessed the potential future radiation doses attributable to the

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4 The Government of France covered most of the direct costs of the Study. Significant in-kind contributions were made by Argentina, Australia, Austria, Belarus, Belgium, Cuba, Denmark, Fiji, Germany, Indonesia, Japan, the Republic of Korea, New Zealand, Norway, the Russian Federation, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, the United States of America, the European Commission, the South Pacific Forum, the South Pacific Regional Environment Programme, the Office of FAO's Sub-Regional Representative for the Pacific, WHO and UNSCEAR. In addition, substantial in-kind contributions were made by the various laboratories involved in the Study. The Government of France provided invaluable logistic assistance throughout the Study.

residual radioactive material which is presently located in the cavities of the safety trials and in the cavity-chimneys of the nuclear tests beneath the atolls.

- Task Group B (supported by the "Source term", "Geosphere radionuclide transport" and "Marine modelling" Working Groups) estimated the rate at which the residual radioactive material in the safety trial cavities and the nuclear test cavity-chimneys might migrate through the geosphere and be released into the surrounding ocean, either directly or through the atoll lagoons, and ultimately dispersed through the South Pacific Ocean - thereby providing the basis for the assessment of long-term doses attributable to this material.

Environmental sampling and surveillance campaign

(9) The Study involved an environmental sampling and surveillance campaign at Mururoa and Fangataufa Atolls, which provided the basis for evaluating a large amount of available data (mostly from French sources). The campaign was split into a terrestrial part, covering the surface soils and corals and the flora of the atolls, and an aquatic part, covering the atoll lagoons, the surrounding ocean and their biota. The terrestrial part involved the collection of about 300 samples (vegetation, coconuts, sand, soil, corals, cores of coral bedrock, and aerosols), a large analytical effort (over 1000 radioanalytical determinations) and more than 100 *in-situ* gamma spectrometry measurements. The aquatic part involved gamma-spectrometric surveys of the seabed, in order to optimize sampling, and the collecting of over 300 samples of lagoon water, ocean water, sediment pore water, sediment, corals and biota. Some 13000 litres of water and about 1000 kilograms of solid samples were analysed, also representing a large analytical effort. No restrictions were placed by the French authorities on the sampling and surveillance campaign.

The present radiological situation

(10) The aim of the assessment of the present situation was to estimate the radiation doses that people would receive from the radionuclides in the residual radioactive material that is already present in the accessible environment of Mururoa and Fangataufa Atolls and their surrounding waters. The values used for the present activity levels of radionuclides were based on the available data evaluated and supplemented through the sampling and surveillance campaign carried out at the atolls.

(11) There are no records of previous permanent indigenous habitation of Mururoa and Fangataufa Atolls, although there has been some intermittent habitation of Mururoa Atoll in addition to the habitation of both atolls by personnel involved in the programme of *expériences nucléaires*. However, the Study postulated hypothetical dwellers on the atolls and assessed the radiation doses that might be received by them. The hypothetical dwellers were presumed to eat largely local seafood and locally grown produce. By making conservative assumptions about diet and mode of living, the Study estimated an upper limit to the doses that might be experienced if the atolls were actually to be inhabited. Also, the Study

provided a conservative estimate of the doses being received by the present population of Tureia Atoll, the nearest inhabited land to Mururoa and Fangtaufa Atolls, located at about 130 km from them.

The potential future radiological situation

(12) The aim of the long-term assessment was to estimate the hypothetical doses that people anywhere in the South Pacific region might receive (in addition to the doses attributable to the residual radioactive material that is now already present in the accessible environment of the atolls) as a result of the release of residual radioactive material presently underground at the Mururoa and Fangataufa Atolls into the atoll lagoons or directly into the surrounding ocean. Such a release could be caused by the normal migration of the residual radioactive material through the geosphere (modified by the hydrogeological effects of the nuclear testing) or by the occurrence of *disruptive events*. The assessment involved four steps.

(13) The initial step was an assessment of the yield of each nuclear test using seismic monitoring information from various sources - mainly from New Zealand. The specific characteristics of each nuclear device and each nuclear test were not provided by the French Government for the Study, but it was possible to assess independently the total *inventory source term*, i.e. the activity presently underground at Mururoa and Fangataufa Atolls of all radionuclides in the residual radioactive material generated by each nuclear test, by making assumptions about the design of the nuclear devices on the basis of their yields and the materials used in their assembly.

(14) The second step was to assess the *effective source term* to be used in calculating the dispersion of the released residual radioactive material into the ocean, i.e. the rate at which the radionuclides in each nuclear test cavity-chimney might escape into the lagoons or directly to the ocean. This was a two-stage process: first, the concentration of each radionuclide dissolved in the saline water filling each cavity-chimney was estimated; second, the rate of migration of the dissolved material through the surrounding basalt basement and through the carbonate formations was modelled. An independent check on the validity of the assumptions made in the Study's calculation of nuclear test cavity-chimney water concentrations was carried out by comparing the Study's estimates with independently measured concentrations in water samples collected from two nuclear test cavity-chimneys.

(15) Modelling of the migration of radionuclides through the basalt basements into the carbonate formations was carried out using a dual-porosity model developed for the assessment of underground waste repositories. The modelling calculations took account of flow in the fractures[5] and of the retention of some radionuclides on surfaces within the basalt

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[5] The effects of the underground nuclear tests on the geological structures and on the stability of Mururoa and Fangataufa Atolls were not within the terms of reference of the Study, except insofar as geological pathways for radionuclide transport to the biosphere may have been affected by the explosions. The possibility that migration may have been enhanced by the explosions was examined. The geological consequences of the nuclear test programme for Mururoa and Fangataufa Atolls, including the issue of geological stability, were the subject of a detailed investigation carried out at the request of the French Government by a group of earth scientists (an *ad hoc* International Geomechanical Commission, IGC). The IGC investigation was independent of the Study, although three scientists participated in both.

rock matrix. The velocity of water flow, assumed constant, was determined by hydrological modelling. Calculations were carried out for 32 radionuclides, but particular attention was paid to 3 radionuclides of potential radiological significance – ^{239}Pu, ^{137}Cs and ^{90}Sr – and to ^{3}H, which was a useful tracer for model validation. The predicted inventory in the carbonate formations was compared with estimates based on concentrations of radionuclides in the underground waters of the carbonate formations as determined by French scientists, supplemented by the Study's independent measurements. Future rates of radionuclide release from the carbonate formations, either upwards to the lagoons or laterally to the ocean at depth, were estimated using a semi-empirical mixing model.

(16) In order to simplify the assessment of the total effective source term, i.e. the releases as a function of time from all underground nuclear tests, the Study divided the nuclear tests into categories and then determined the integrated release rate for each category. Three categories of nuclear test were the most important contributors to the overall release rates: 12 nuclear tests (carried out at Mururoa Atoll early in the nuclear test progamme) in which the top of the cavity-chimney penetrated into the carbonate formations; four nuclear tests (three at Mururoa Atoll and one at Fangataufa Atoll) in which the basalt basement surrounding the cavity, though apparently thick enough, was inadequate to ensure complete confinement; and four safety trials (carried out in the carbonate formations at Mururoa Atoll - with no release of fission energy) which were found to be the major sources for the long-term release of plutonium.

(17) The Study also examined a number of hypothetical disruptive events, including *extreme events* and *events due to climatic changes,* that could lead to enhanced rates of release of the material presently in the cavity-chimneys or to enhanced rates of exposure to material in the environment (e.g. to the plutonium in the sediments). The consequences of only one disruptive event were considered worth investigating further: a hypothetical extreme event consisting of a major breakaway and slide of the carbonate formations in the northern zone of Mururoa Atoll, in the area where the underground safety trials and some of the nuclear tests that produced cavity-chimneys penetrating into the carbonate formations were carried out. It was assumed that this slide would intersect a safety trial cavity and also a nuclear test cavity-chimney which had penetrated into the carbonate formations, and pessimistic assumptions were made about the fraction of the exposed material that might be released instantaneously.

(18) The third step was to use the effective source term at different times in modelling the dispersion of the released material through the South Pacific Ocean and in calculating the future concentrations of the radiologically significant radionuclides at a number of selected sites in the South Pacific Ocean at various times.

(19) The final step in the evaluation was to estimate the dose rates to which critical groups of people would be exposed at those places and times for which future concentrations of radionuclides had been calculated. It was through consideration of the implications of the present and future estimated dose rates that the IAC came to its findings about the

radiological situation at the atolls and to its conclusions and recommendation about remedial and other actions.

REPORTS RESULTING FROM THE STUDY

(20) In March 1998, the IAC approved its reports on the Study of the Radiological Situation at the Atolls of Mururoa and Fangataufa, which are being issued by the IAEA in its Radiological Assessment Reports Series. These reports are: a ***Main Report***, which incorporates this *Executive Summary*; a ***Technical Report*** in six volumes ("*Radionuclide Concentrations Measured in the Terrestrial Environment of the Atolls*", "*Radionuclide Concentrations Measured in the Aquatic Environment of the Atolls*", "*Inventory of Radionuclides Underground at the Atolls*", "*Releases to the Biosphere of Radionuclides from Underground Nuclear Weapon Tests at the Atolls*", "*Transport of Radioactive Material within the Marine Environment*" and "*Doses due to Radioactive Materials Present in the Environment or Released from the Atolls*"); and a ***Summary Report*** for the benefit - in particular - of persons with executive, managerial and administrative responsibilities. The IAEA has also issued a public information booklet relating to the Study.

FINDINGS

Residual radioactive material already present in the accessible environment of the atolls

(21) The Study found that the terrestrial and aquatic environments of Mururoa and Fangataufa Atolls that are accessible to people contain residual radioactive material attributable to the *expériences nucléaires*, but at generally very low concentrations which the Study concluded were of no radiological significance. There are, however, some features of note whose radiological implications are examined in paragraph (24):

(a) Several kilograms of plutonium resulting from the atmospheric nuclear tests carried out at the atolls remain in sediments under the lagoon of each atoll. Some of the plutonium in the sediments of the Mururoa Atoll lagoon came from the atmospheric safety trials.

(b) The concentration of tritium in each lagoon was found to be higher than in the open ocean, as the result of leakages from a number of the cavity-chimneys created by underground nuclear tests.

(c) Particles containing plutonium and small amounts of americium resulting from atmospheric safety trials remain in the area of the trial sites - the motus of Colette, Ariel and Vesta on Mururoa Atoll. The Study analysed these types of particles, found in samples of sand and coral collected from the surface of the motu of Colette and in sand taken from a sandbank adjacent to it.

(d) Elevated levels of ^{137}Cs were found over small areas totalling several hectares on the Kilo–Empereur rim of Fangataufa Atoll.

Residual radioactive material underground at the atolls

(22) The Study found that the results of the assessments of the nuclear explosive yields of all underground nuclear tests and of the resulting inventories of residual radioactive material contained underground at the atolls are in good agreement with information made available for the Study from French sources.[6]

(23) From the measurements of the activity in underground water samples taken from the two cavity-chimneys selected for the *in-situ* sampling, the Study found that the concentrations of highly refractory radionuclides, in particular of $^{239+240}Pu$, are extremely low, indicating a high level of retention of such radionuclides in the glass-like lava formed in the cavities by basalt rock melted in the underground explosions.

Potential radiation doses due to residual radioactive material already present in the accessible environment of the atolls

(24) Although it is doubtful whether Mururoa Atoll - still less Fangataufa Atoll - could sustain a permanent population dependent solely on local resources for food, the Study assessed the radiation doses to hypothetical inhabitants that could result from the residual radioactive material at present in the terrestrial and aquatic environments of the two atolls. The Study found that a population permanently resident on the atolls, and living on a diet of local produce and seafood, would not generally receive a radiation dose attributable to the residual radioactive material exceeding 0.01 mSv per year, which is equivalent to a very small fraction (less than one part in 200) of the annual background radiation dose that such a resident population would unavoidably receive from natural radiation sources. The Study found it necessary, however, to examine specifically the four features of note identified in paragraph (21):

(a) *Plutonium in the lagoons*: The Study found that the inventory of plutonium in the sediments of the two lagoons, while large, is of little radiological significance, mainly because of the low rate of transfer of plutonium to people via feasible pathways. Also, the Study noted that the availability of the plutonium will decrease over time owing to (i) the removal of the lagoon sediments to the ocean and (ii) the gradual burial and dilution of lagoon sediments by the accumulation of fresh sediment.

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[6] The Study estimated the total yields, calculated from the sum of the yields of individual nuclear tests, to be 2400 kilotons (one kiloton being equivalent to one thousand tons of trinitrotoluene [TNT]) for Mururoa Atoll and 770 kilotons for Fangataufa Atoll; the values provided by the French Liaison Office were 2400 kilotons and 800 kilotons. (Most experimental and theoretical values for the explosive energy released by TNT range from 900 to 1100 calories per gram. At one time, there was uncertainty as to whether "kiloton" of TNT referred to a "short" kiloton, a "metric" kiloton or a "long" kiloton. In order to avoid ambiguity, it was agreed that the term "kiloton" should refer to the release of 10^{12} calories of explosive energy.)

(b) *Tritium in the lagoons:* Similarly, the Study found that concentrations of tritium in the lagoons are of no radiological significance even though they are at present higher than in the open ocean.

(c) *Plutonium-containing particles:* The Study noted that, if an individual were to visit the motus of Colette, Ariel or Vesta at Mururoa Atoll, there is a possibility that a particle containing plutonium with small amounts of americium could be incorporated into that individual's body - for example, through a cut caused by a fall. The Study assessed the probability of the incorporation of such a particle and its long-term retention within the body. It also assessed the associated radiation dose and the probability of harm as a result of the dose received. On this basis, the Study found that the probability that a hypothetical individual visiting and spending some time on any of the three motus would ultimately incur a fatal cancer attributable to the incorporation of a particle containing plutonium is less than one in one million per year.

(d) *Caesium-137 on the Kilo-Empereur rim:* The Study found that, if any population were to subsist entirely on produce grown on small areas of the Kilo–Empereur rim of Fangataufa Atoll, the estimated maximum radiation dose attributable to the ^{137}Cs in the rim would be about 0.25 mSv per year, equivalent to about one tenth of the total radiation dose which that population would unavoidably receive as a result of natural radiation sources. The Study considers, however, that this hypothetical situation is highly unlikely to arise, since - *inter alia* - the Kilo-Empereur rim is almost barren and virtually uninhabitable by people adopting a traditional semi-subsistence lifestyle.

(25) The Study found that the highest dose attributable to the residual radioactive material already present in the accessible environment of Mururoa and Fangataufa Atolls, which is estimated to be currently received by residents of Tureia Atoll, is less than 0.0001 mSv per year, which is a completely insignificant fraction (about one part in 10 000) of the annual background radiation dose that these residents will unavoidably receive from natural radiation sources. It should be noted, however, that Tureia Atoll did receive some immediate fallout from the atmospheric nuclear tests carried out at Mururoa and Fangataufa Atolls, in addition to the fallout globally experienced as a result of all atmospheric nuclear testing. The radiation doses currently being received by residents of Tureia Atoll as a result of residues from earlier fallout and due to the nuclear testing at Mururoa and Fangataufa Atolls were assessed and found to be about 0.005 mSv per year, which is an extremely small fraction (about two parts in 1000) of the annual background radiation doses that the residents will unavoidably receive from natural radiation sources.

(26) The radiation doses due to the residual radioactive material already present in the accessible environment - principally arising from ^{137}Cs and plutonium isotopes - will persist, but they will decline owing to both radioactive decay and other processes that reduce the availability of these radionuclides in the environment. According to the Study estimates, the rate of leaching of the ^{137}Cs and the plutonium isotopes present in the lagoon sediments will continue to decrease with time, as will the estimated radiation doses associated with these

radionuclides. The Study found that the highest estimated potential annual doses attributable to the residual radioactive material already present in the accessible environment of Mururoa and Fangataufa Atolls and their surrounding waters will decline from the present hypothetical maximum of no more than 0.01 mSv per year to about 0.001 mSv per year within 100 years.

Migration of residual radioactive material from underground

(27) The Study estimated the rate of migration of the radionuclides in the radioactive material produced by the underground nuclear tests from the cavity-chimneys, through the geological media, into the lagoons and directly into the ocean over periods of more than 100 000 years. The Study found that, over the first few decades, most of the released radionuclides would come from the small number of underground nuclear test sites where the basalt basement above the nuclear test point provided inadequate confinement of the nuclear tests.[7] In terms of amounts of activity, tritium would dominate the early releases, but with activity concentrations that are of no radiological significance. Other radionuclides, including ^{137}Cs and ^{90}Sr, would be effectively retained underground within the basalt basement, most of their activity decaying and only small amounts of activity being released. Plutonium would continue to be released over long periods of time but at very low rates. The modelling predicts that concentrations of ^{137}Cs and $^{239+240}Pu$ in the lagoon water are unlikely to exceed present levels at any time in the future. The concentrations of ^{90}Sr and ^{3}H could rise marginally above current levels, but only during the next few decades.

Dispersion of residual radioactive material throughout the ocean

(28) The Study used regional and far field oceanographic models to estimate the concentrations in sea water at various locations and times of radionuclides released into the ocean from Mururoa and Fangataufa Atolls. The Study found that, except as a consequence of a hypothetical extreme disruptive event (see paragraph (29)), the predicted long-term concentrations of radionuclides decrease to background oceanic levels beyond about 100 km from the atolls; thus, at Tureia Atoll the predicted concentrations will be around background levels and of no radiological significance.

Consequences of postulated disruptive events

(29) The only disruptive event that was found by the Study to warrant a thorough assessment was the hypothetical major breakaway and slide of the carbonate formations in the northern zone of Mururoa Atoll, in the area where the underground safety trials and some of the nuclear tests producing cavity-chimneys which penetrated into the carbonate formations were carried out. If such a hypothetical extreme event were to occur, ocean currents would carry the released radioactive material away from Mururoa Atoll and the highest potential annual dose would therefore be received by residents of nearby atolls. For

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7 This inadequate confinement is caused by fractures in the basalt basement which reach from the cavity-chimneys to the carbonate formations above.

the residents of Tureia Atoll, the dose in the first year following such a slide would not be more than a few thousandths of a millisievert - which is an extremely small fraction (a few parts in 1000) of the annual background radiation dose that the residents will unavoidably receive from natural radiation sources - even pessimistically assuming that all the plutonium involved in the slide went into solution.

Potential doses in the future

(30) The Study found that - except in the hypothetical situation discussed in paragraph (24) - no population group is likely to receive at any time in the future a dose attributable to the residual radioactive material at Mururoa and Fangataufa Atolls which exceeds approximately 1% of the background radiation dose that the group will unavoidably receive from natural radiation sources.

CONCLUSIONS

Implications for human health

(31) The Study concluded that **there will be no radiation health effects which could be either medically diagnosed in an individual or epidemiologically discerned in a group of people** and which would be attributable to the estimated radiation doses that are now being received or that would be received in the future by people as a result of the residual radioactive material at Mururoa and Fangataufa Atolls.

(32) Nevertheless, the Study noted that the reported cancer incidence in populations in the South Pacific region and throughout the world is changing for a number of reasons, including: the improved diagnosis and registration of cancer cases; modifications in environmental exposure to cancer-causing agents and in personal habits (such as dietary and smoking habits); population migrations that alter baseline cancer incidence rates; and changes in the incidence of other diseases. The Study emphasized, however, that at the very low levels of dose estimated in the Study there will be no changes in cancer incidence rates in the region attributable to radiation exposure caused by the residual radioactive material at Mururoa and Fangataufa Atolls.

Implications for biota

(33) The Study assessed the dose rates to native biota resulting from the residual radioactive material at Mururoa and Fangataufa Atolls and, in the great majority of cases, found them to be similar to or lower than dose rates due to natural radiation sources. An exception is the potentially high dose rates that could be experienced by individual members of some species owing to plutonium contained in particulates - for example, from the sediment of the sandbank adjacent to the Colette motu in the northern part of Mururoa Atoll. Overall, the Study concluded that **the expected radiation dose rates and modes of exposure are such that no effects on biota population groups could arise**, although occasionally individual

members of species might be harmed, but not to the extent of endangering the whole species or creating imbalances between species.

Remedial actions

(34) Given the measured and predicted radionuclide activity levels, and the low dose levels estimated for the present and for the future, and with account taken of international guidance, the Study concluded that **no remedial action at Mururoa and Fangataufa Atolls is needed on radiological protection grounds, either now or in the future**.

Monitoring

(35) Similarly, the Study concluded that **no further environmental monitoring at Mururoa and Fangataufa Atolls is needed for purposes of radiological protection**.

Robustness of the conclusions

(36) Although many assumptions were made in the modelling of systems, the findings are robust: i.e. the Study concluded that **the expected extent of changes in the conclusions due to uncertainties in the parameters used in the modelling is slight**. Furthermore, the predicted doses are so low that large errors (even of an order of magnitude) would not affect the conclusions.

RECOMMENDATION

(37) The Study noted that a scientific programme of monitoring of the radionuclide concentrations in the carbonate formations and in the nuclear test cavity-chimneys is under way at Mururoa and Fangataufa Atolls. Should this programme continue, the Study recommends that emphasis be placed on monitoring the migration behaviour of long-lived and relatively mobile radionuclides and radiocolloids because of its particular scientific interest. The scientific programme, supplemented by some monitoring of radionuclide levels in the biosphere, may also be useful in assuring the public about the continuing radiological safety of the atolls.

Note: Ciguatera

Ciguatera is a type of food poisoning brought about by eating fish contaminated by a neurotoxin generated by a marine micro-organism often found in association with disturbed coral reefs. There have been some reports in news media that outbreaks of ciguatera may be linked to exposure to radiation from the residual radioactive material at Mururoa and Fangataufa Atolls. The symptoms of ciguatera poisoning have been recognized for over a century and a range of anthropogenic and natural disturbances may contribute to ciguatera

outbreaks. However, there is no evidence in the scientific literature of radiation exposure being a causal factor.

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DISCUSSION IN THE BOARD OF GOVERNORS ON THE STUDY OF THE RADIOLOGICAL SITUATION AT THE ATOLLS OF MURUROA AND FANGATAUFA (11 June 1998)

1. The CHAIRMAN recalled that at the request of France, and in consultation with the Board, the Secretariat, in co-operation with the International Advisory Committee established to supervise the exercise, had undertaken a study of the radiological situation at the atolls of Mururoa and Fangataufa. An Executive Summary of the Main Report was contained in document GOV/1998/14 and the Board was invited to take note of it and authorize its submission to the forty-second regular session of the General Conference.

2. Mr. BENINSON (Argentina) thanked the Director General for keeping the Board of Governors continuously informed on the progress of the study on the radiological situation at Mururoa and Fangataufa and commended the Secretariat on the preparation of the Executive Summary attached to document GOV/1998/14.

3. His Government had participated actively in the study and was gratified that the Agency had completed, within the established time frame, an exercise which had been one of the largest technical undertakings in the history of the IAEA. Although the Agency had carried out evaluations of residues from the Cold War era in the Marshall Islands and in Kazakhstan, the present study was the first conducted at the request of one of the nuclear-weapon States and the first that had been absolutely comprehensive, including not only residues from atmospheric nuclear tests but also residues from underground tests.

4. His Government welcomed the step taken by the Government of France in requesting the study, which had been in the spirit of the resolution on nuclear testing adopted by the General Conference in 1995,[1] and appreciated the great financial, logistic and scientific efforts which had been necessary in order to make the study possible.

5. The Government of Argentina also wished to thank expressly all States, institutions, laboratories and scientists that had contributed to the study. While it was difficult to single out anyone for praise among such a large number of eminent scientists, it could be said that, if one man exemplified the efforts of the many professionals who over the years had made the Agency into a technical institution commanding worldwide respect, that was the Technical Project Manager, Mr. Robert Fry of Australia. He was a scientist of considerable reputation in the field of radiation protection who had served the Agency on many occasions, dealing with some very sensitive issues. For instance, in 1973 he had been asked to chair the difficult negotiations on the definition of radioactive materials for the London Convention. Since then

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[1] GC(39)/RES/23.

his contributions to his profession, his country and the Agency had been remarkable. Before the present study had started he had been enjoying a quiet retirement, but when the Agency and his own Government had called upon him he had risen to the occasion, and had served the Agency once again in an exemplary manner.

6. In conclusion, the Government of Argentina supported the recommendations contained in paragraph 9 of document GOV/1998/14 and requested the Director General to transmit the document and the Executive Summary to the General Conference for consideration at its forty-second regular session.

7. Mr. PRETTRE (France) recalled that, having taken the decision to close its nuclear testing site definitively, the French Government had asked the Director General whether the Agency could conduct a scientific study to evaluate the radiological situation on the atolls of Mururoa and Fangataufa, in French Polynesia.

8. To that end, an International Advisory Committee chaired by Ms. Gail de Planque had been set up consisting of independent scientific experts supported by a network of laboratories working in co-ordination with the IAEA with the support of the French Government.

9. The results of that study, a summary of which was now before the Board in document GOV/1998/14, would be discussed in detail at an international conference to be held in Vienna from 30 June to 3 July 1998.

10. France wished to thank the Chairman of the International Advisory Committee, Ms. de Planque, as well as the Chairmen of the task groups and working groups and all the experts from all the participating countries and laboratories who had contributed to the successful completion of the study. It further wished to thank the Governments of Argentina, Australia, Austria, Belarus, Belgium, Cuba, Denmark, Fiji, Germany, Indonesia, Ireland, Japan, the Republic of Korea, New Zealand, Norway, the Russian Federation, Slovenia, Spain, Sweden, Switzerland, the United Kingdom and the United States of America, and also the European Commission, the South Pacific Forum, the South Pacific Regional Environment Programme, the Subregional Office for the Pacific Islands of the Food and Agriculture Organization of the United Nations, the World Health Organization and the United Nations Scientific Committee on the Effects of Atomic Radiation, for their various contributions to the study. Finally, it thanked the Agency's Secretariat for managing the project and for organizing the international conference.

11. The report to the Board showed that the study had been extremely thorough with exemplary co-operation between his country and the Agency. France had made every effort to supply the members of the International Advisory Committee with the most detailed information available in complete transparency.

12. His Government noted with satisfaction that the report's conclusions confirmed the consistent statements of the French authorities that the nuclear tests had been conducted with

all necessary precautions to ensure the absence of immediate or long-term effects on the health of the region's population and on the environment.

13. Mr. BIGGS (Australia), welcoming the document, noted that the invitation to the Agency to conduct the study largely fulfilled the responsibility arising from General Conference resolution GC(39)/RES/23 "to ensure that sites where nuclear tests have been conducted are monitored scrupulously and to take appropriate steps to avoid adverse impacts on health, safety and the environment as a consequence of such nuclear testing".

14. The study had a special significance for countries in the South Pacific region in view of concerns there about the effects of nuclear testing. It had been conducted by an independent team of reputable scientists and institutions, including several from Australia, and had produced an authoritative scientific assessment of the radiological situation at the atolls.

15. His country appreciated the comprehensive presentation arranged by the Agency in Nadi, Fiji, on 2 June and looked forward to the outcome of the international conference to be held in Vienna at the end of the month.

16. Mr. SILVA HENNINGS (Chile)* congratulated the Agency on the excellent study carried out at Mururoa and Fangataufa and on the document submitted to the Board. He expressed appreciation to the Government of France for requesting the study, and also thanked the International Advisory Committee and the countries and organizations which had contributed to it.

17. The radiological situation in the area concerned was of great interest to his country in view of its geographical location, and his delegation was pleased to note the results indicating that the radiological situation of the atolls and the surrounding ocean and biota was not such as to cause problems for the health of the population or the environment. That conclusion reduced his country's concerns regarding the effects that the radiological situation in the atolls might have on its own coastal populations and marine environment.

18. Mr. LEE (World Health Organization), noting that his organization had collaborated with the Agency on a number of human health topics for a long time, said that WHO had attached great importance to its participation in the study as a member of the International Advisory Committee because of the implications for human health. The study had been of the highest scientific quality and had been very well organized by the Agency, and WHO was satisfied with the outcome and with the conclusion that present and future effects on human health were negligible.

19. In conclusion, he thanked the Government of France and the many other governments which had been involved in the study for their generous support.

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* Member States not members of the Board of Governors are indicated by an asterisk.

20. Mr. STOIBER (United States of America) took note of the document before the Board and commended the Secretariat on the completion of that very important work. He also thanked the Government of France for the contribution it had made. The Government of the United States considered that type of work to be of importance in assessing both the impact of nuclear testing and the effects of long-lived radioisotopes on the environment and, potentially on populations. His Government would be interested in any follow-up work undertaken, to see how the results of the study might be applied in other areas by the Agency or other members of the nuclear community.

21. The CHAIRMAN, summing up the discussion, said that the Board had commended the Secretariat for the report contained in document GOV/1998/14 and expressed its appreciation to the members of the International Advisory Committee. He assumed that the Board wished to take note of the information contained in document GOV/1998/14 and authorize its transmission to the General Conference.

22. It was so decided.

International Conference on the Radiological Situation
at the Atolls of Mururoa and Fangataufa

CONCLUSIONS AND CLOSING REMARKS

by

Eduardo Bobadilla López

President of the Conference

Director General of the International Atomic Energy Agency; participants in this International Conference on the Radiological Situation at the Atolls of Mururoa and Fangataufa; members of the International Advisory Committee and of the Task Groups and Working Groups which carried out the impressive Study discussed during this week; representatives of the French Government; officers of the Agency; observers from governmental and non-governmental organizations; representatives of the media; ladies and gentlemen.

As we come to the end of this Conference, it is my duty and my pleasure to convey to you my impressions and conclusions regarding the deliberations of the Conference and the subject matter which the Agency convened us all to consider - namely, the current and future radiological impact of the residual radioactive materials remaining from the nuclear weapon testing carried out in the South Pacific over the past three decades.

You have received for your scrutiny the Main Report of the Study on the Radiological Situation at the Atolls of Mururoa and Fangataufa, which was organized by the Agency at the request of the French Government. You have also received six bulky technical volumes supporting this report, plus a summary report designed to guide you through the Study - all in all, some 1300 pages of technical material. In the light of all this material, I wish to reconfirm the impression that I conveyed to you at the opening of the Conference: we have had the opportunity to review one of the most comprehensive radiological studies of radioactive residues in the environment ever carried out at the international level. After going through a massive amount of detailed technical information this week, we should again acknowledge:

- firstly, the work of the many experts who generously invested so much time, effort and expertise in the Study,
- secondly, the openness of the French Government in requesting a thorough radiological assessment in territories under its control, and
- thirdly, the efforts of the International Atomic Energy Agency in organizing and managing such an impressive endeavour.

Before going on to summarize the work of the Conference, I wish to present my general conclusions and reflections.

It is evident to me from the Study (and the discussions during the week confirm this) that - fortunately - the radiological impact from the residual radioactive materials remaining from the period of nuclear testing at Mururoa and Fangataufa is absolutely negligible. This scientific finding is the positive news from the Conference for the people of the South Pacific, who include the people of my own country. For me, as a medical doctor who has devoted his professional life to people's health, it is indeed good news.

However, let me emphasize something that has been said repeatedly during the week. This good news should not be interpreted as condoning the practice of nuclear weapon testing, either in the South Pacific or in any other part of the world. In my opinion, nuclear weapon testing is not only a grave offence against the environmental habitat, but also - and more importantly - incompatible with ethical principles. Therefore, it should be condemned with all the force at our disposal. Let me state from this podium that the world has experienced more than two thousand nuclear weapon tests TOO MANY! I call on all States to stop this practice once and for all.

At the same time, I submit that this Conference was very glad to learn:

- first, that the Agency's General Conference has already called on all States concerned "*to fulfil their responsibilities to ensure that sites where nuclear tests have been conducted are monitored scrupulously and to take appropriate steps to avoid adverse impacts on health, safety and the environment as a consequence of such nuclear testing*", and

- second, that two States besides France have already requested international assessments of the residual radioactive material from nuclear weapon testing carried out in their territories and that, in addition to the Study at Mururoa and Fangataufa, a study has already been conducted - and the results published - on the prospects for resettlement of the Bikini Atoll in the Republic of the Marshall Islands and a preliminary study has been conducted at Semipalatinsk in Kazakhstan - with the results soon to be issued by the Agency.

The news from these two studies is far from being as good as the news from the Mururoa and Fangataufa Study, but bad news can be converted into good news if proper action is taken. I hope that the remedial measures necessary for resettlement of the Bikini Atoll will be taken and that a comprehensive study will be carried out at Semipalatinsk with a view to ensuring that appropriate remedial measures are taken there.

In this context, I reiterate the call I made at the opening of the Conference to all other States which have conducted nuclear weapon tests or in whose territories nuclear weapons

have been tested to request the competent United Nations body - the International Atomic Energy Agency - to carry out scrupulous assessments, in collaboration with other specialized organizations, of the current radiological situation at all former test sites and to provide for the application of international standards for the protection of people from the potential effects of ionizing radiation.

After these general conclusions and reflections, let me now turn to the details of the Conference.

We first of all benefited from a background seminar which set the scene for the Conference:

- The French nuclear test programme at Mururoa and Fangataufa was described in detail by the Directeur Adjoint de la Direction des Applications Militaires du Commissariat à l'Energie Atomique, Monsieur Barthoux, representing the French Government. We learned that France's nuclear test programme began in 1960, with a series of atmospheric tests. The first four tests, of low yield, were conducted in Algeria, at a site in the Sahara desert. In 1962, a decision was taken to establish a test site in the South Pacific, at Mururoa Atoll, 460 km to the south of an air base at Hao and 1200 km to the south-west of a main logistical base on Tahiti. Mururoa had the advantage of being uninhabited and remote from populated areas. Atmospheric tests at the South Pacific test site occurred from 1966 to 1974; 37 tests were conducted at Mururoa and four tests at nearby Fangataufa Atoll. Following the cessation of atmospheric testing, an underground test programme began; it lasted from 1975 until January 1996. Of the 137 underground tests, 127 were conducted at Mururoa and ten at Fangataufa. In addition to nuclear tests, a series of safety trials was carried out at Mururoa. In these, nuclear devices were subjected to simulated accident conditions with destruction by conventional explosives. In summary, 193 tests (including safety trials) with a total yield of 13 megatons were conducted during the French nuclear test programme, which ceased on 27 January 1996. The Conference was pleased to learn that the test site facilities are being dismantled and that the site will be closed.

- The framework of the Study was described by the Chairman of the International Advisory Committee, Dr. Gail de Planque.[1] Dr. de Planque reminded us that the Study had been prospective in nature and that it had not been within the terms of reference of the Study to assess retrospectively doses received by inhabitants of the region as a result of the atmospheric nuclear tests at the time when those tests were carried out (doses due in part to the fallout of radioactive material that included

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1 See the Main Report on the Radiological Situation at the Atolls of Mururoa and Fangataufa (Report by an International Advisory Committee, in the International Atomic Energy Agency's Radiological Assessment Reports Series), sub-section 1.2.1.

short-lived radionuclides). She recalled, however, that an assessment of exposures of all countries as a result of atmospheric testing had been carried out by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), with the findings reported to the General Assembly of the United Nations and to the world scientific community; it had therefore not been necessary to include an evaluation of past atmospheric tests in the Study. Nevertheless, for completeness and in order that the present and future radiological situation at the test site may be better understood, details regarding the radiation doses attributable to atmospheric testing at the atolls have been reported.[2]

- The background seminar was therefore completed by a presentation of the Director of the UNSCEAR Secretariat, Dr. Burton Bennett, who provided to the Conference a comprehensive summary of the UNSCEAR findings.[3] The Conference was pleased to learn that the atmospheric tests conducted by France made a relatively low contribution to the total yield of the tests conducted by all countries; the number of atmospheric tests conducted by France was less than 10% of the total number of atmospheric tests conducted by all countries and the total yield of the French tests was only just over 2% of that of all tests. Many measurements have been made throughout the world of the dispersion and deposition of radionuclides produced in atmospheric tests, and an accurate assessment can be made of the deposition and doses from individual tests or from test series. The latitude band receiving the greatest deposition from the French atmospheric tests was the 20-30° band in the southern hemisphere. Even there, the deposition from the tests conducted by other countries was five times higher than that from the French tests. During the period of maximum cumulative deposition, from 1962 to 1972, the average dose rate to persons residing at latitude 20-30° south was extremely low - a few tens of microsieverts per annum, of which 20% can be attributed to French atmospheric testing. The maximum dose rate has since decreased by an order of magnitude. The present dose rates are two to three orders of magnitude less than the annual background rate due to natural radiation sources.

In spite of the fact that these initial presentations were intended only to set the scene for the subsequent technical sessions, there was some discussion. For instance, an observer from a non-governmental organization asked whether fallout from the atmospheric tests had reached inhabited islands and whether information had been sought from people who had been working on Mururoa and Fangataufa at the time of the tests and who are now living on Tahiti. The ensuing discussion made it clear that after the atmospheric tests there was fallout of residual materials not only over inhabited islands in the South Pacific but throughout the southern hemisphere; the data are in Annex I to the Main Report (Tables I-I, I-II and I-III). Because of the remoteness of the test site, however, local exposures occurred after only five

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[2] Op. cit., Annex I.

[3] Op. cit., Annex I.

of the atmospheric tests. Residents of the Gambier Islands may have received doses of about 5 mSv following the first atmospheric test, of 2 July 1966, when winds and rainfall caused local deposition. Doses of 1 mSv or less were estimated for the four other tests. These doses are of the same order as annual doses from natural radiation and are thus not of radiological significance. As to information on workers and occupational doses, the ensuing discussion made it clear that a representative of the Project Management Office had candid talks with workers' representatives at a briefing meeting for people of French Polynesia that took place recently at the University of the South Pacific, Faaa. It was stated that it is not possible to determine in retrospect doses received in the past. According to international practice, and the requirements of the International Labour Organization, it is the responsibility of employers to monitor occupational doses. The Conference understands that the French authorities will soon be issuing a report on this matter.

And thus we moved into the technical sessions.

The first technical session provided us with an overview of the current radiological situation, including the residual radioactive materials present in the accessible terrestrial and aquatic environments of the atolls.[4] Descriptions were given of the terrestrial and aquatic surveillance campaign, of the residual radioactive materials on Colette motu, Mururoa Atoll, and of the radionuclide releases into the ocean. It is clear, I believe, that the terrestrial and aquatic environments of the atolls that are accessible to people contain residual radioactive materials attributable to the testing, but at generally low concentrations. It is also clear that, in addition to the several kilogrammes of plutonium that remain in sediments of the lagoon of each atoll, particles containing plutonium resulting from atmospheric safety trials remain in the area of the trial sites - the motus of Colette, Ariel and Vesta, Mururoa Atoll. Clearly, the concentration of tritium in each lagoon is higher than in the open ocean, and elevated levels of caesium-137 exist over small areas on the Kilo Empereur rim of Fangataufa Atoll.

Let me say here that I was very impressed - as was, I believe, the Conference as a whole - by the big effort involved in the environmental sampling campaign.[5] As a result of prior quality control tests, the relevant French laboratories and the network of laboratories co-ordinated by the Agency laboratories in Seibersdorf and Monaco proved to have a similarly good analytical competence. The Conference was relieved to hear that the results of the environmental sampling campaign showed generally good agreement with values provided by the French authorities. The campaign involved, it was emphasized, a large number of people and laboratories around the world and the collecting of hundreds of samples - vegetation, coconuts, sand, top soil, corals, cores of coral bedrock, aerosols, water from sediment cores, water from the lagoons and the ocean, lagoon sediment, flora and fauna.

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4 Op. cit., sub-section 4.2.

5 Op. cit., sub-section 4.3.

Although the terrestrial sampling and monitoring campaign focused on Mururoa and Fangataufa, the Conference noted that, as there had also been some deposition of radionuclides on nearby islands at the time of the atmospheric nuclear testing, it was decided to carry out some measurements of activity levels at Tureia Atoll. On Tureia, the environmental contamination - partly due to global fallout - was low. In the discussion it was pointed out that the reason why Muruoa and Fangataufa had always been uninhabited, in contrast to Tureia, was frequent inundations.

The Conference noted that each sample had been divided into three, for analysis by the large network of laboratories, for analysis by French laboratories and - very important - for archiving (from where material can be retrieved for subsequent analyses).

The discussion about the small particles containing plutonium and americium which were found in the area comprising the Mururoa motus of Colette, Ariel and Vesta was also very encouraging.[6] The contamination stemmed from safety trials in the area. Even after extensive cleaning by the French authorities, the general level of fixed contamination was estimated by the Study to be perhaps three times the level of the French cleanup criterion. In response to questions it was pointed out that the motus were frequently covered by the sea and much redistribution of sand and coral particles therefore took place. Thus, there are small discrepancies between the French values and the Study values for the plutonium levels on the motus. The discrepancies are probably due to the different survey techniques used. The French technique, which was the only feasible technique for large areas, tended to underestimate the total residual plutonium activity. The small discrepancies do not affect the robustness of the assessment.

As far as the residual radioactive material in the aquatic environment is concerned[7], I believe that the Conference is satisfied with the comparisons with the French data from earlier years: although the Study data show generally lower levels of tritium and some variability for strontium, there is very good agreement for caesium and generally good agreement for plutonium. The open ocean concentrations also showed good correlation for caesium and plutonium. The difference in sampling times between the French measurements and the Study measurements were noted in the discussion. A wide range of samples was collected, including water from sediment pores, the lagoons and the ocean, sediments, corals and biota. Altogether some thirteen thousand litres of water and one tonne of solid samples were collected, processed in situ, and sent to Monaco for distribution to the analytical laboratory network. In order to optimize the sampling, underwater gamma spectrometry was used in surveying the sea bed.

The Conference noted that, by combining the good historical record of activity concentrations obtained from the French data with the recent data points obtained by the Study, it was possible to investigate the time trends in the concentrations of certain key

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[6] Op. cit., sub-section 4.3.1.6.

[7] Op. cit., sub-section 4.3.2.

radionuclides in lagoon water. As I already indicated, the concentration of tritium as measured by the French had been reasonably constant for some years, but the concentration measured by the Study was lower. The constancy of the concentrations was doubtless due to a source of tritium in the carbonate rock; the concentration decrease, as measured by the Study, could have been due to the closing of shafts and the cessation of drilling. This explanation was supported by the correlation between the measured lagoon concentrations and the data on the distribution in carbonate rocks for both lagoons provided by the French authorities. For strontium the concentrations have been stable for some time, which also indicates a possible release to the lagoons from the carbonates. The Conference noted that the main source of caesium is the sediments in the lagoons, so the lagoon concentration is steadily decreasing, with an effective half-life of about ten years, and the concentration of plutonium in the soluble phase is also decreasing, with an effective half-life of about eight years. The inventories of radionuclides - notably plutonium - in the sediments were also calculated, as were the release rates which form the input to the oceanographic modelling.

Now let me turn to the second group of sessions - those relating to the future situation. These sessions were the most complicated - at least for me as a medical doctor - since they covered a wide range of scientific disciplines, showing the overall complexity of the Study.

We were provided first with an overview of the assessment of the future radiological situation. The overall objective of this part of the Study was to estimate the rate at which residual radioactive materials at present underground at Mururoa and Fangataufa Atolls might migrate into the atoll lagoons or directly into the surrounding ocean. The results would be used to estimate the hypothetical doses that local population groups and people anywhere in the South Pacific region might receive in the future. The initial stage was an assessment of the yield of each underground nuclear test in order to determine the radionuclide inventory and how it was partitioned - the inventory source term. The second stage was to assess the rate at which these radionuclides might be released from the cavity-chimneys and migrate through the surrounding rock. This effective source term was the input in modelling the dispersion of the released material and in calculating the future concentration of the radiologically significant radionuclides. The final stage was to estimate the dose rates for critical groups of people. The Conference noted with satisfaction that, as far as possible, the Study had been based on independent data measured as part of the Study and used in independent models.

The Conference noted with interest the detailed assessment of the underground inventory of residual radioactive materials.[8] The activity of residual radionuclides remaining after an underground nuclear test depends essentially on the explosive yield of the nuclear device. In the French information, the yields were given only in three broad ranges and grouped into seven areas for Mururoa and two for Fangataufa. Altogether, the residual radioactive materials underground fell into seven categories - materials from normal tests,

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[8] Op. cit., section 5.

materials from some tests that apparently had inadequate cover and material from some tests in which the cavity-chimney had reached the top of the volcanic rock (CRTV tests); materials from three categories of safety trials, differing according to the rock in which they took place (volcanics or carbonates) and to whether there was a fission yield; and waste plutonium disposed of into two deep repository shafts.[9]

The Conference noted that the yields had been estimated independently, on the basis of seismic monitoring information, mainly from New Zealand sources, and that they agreed well with the total yields reported by the French Liaison Office.[10] Some assumptions, based on the open literature, had to be made regarding weapon design in order to estimate the contribution from nuclear fission and fusion as the first step in determining the underground inventory of radionuclides.[11] The initial large number of radionuclides was reduced to 36 on the basis of selection criteria. This number was greater than the numbers in French studies. In response to a question, it was confirmed that the only information on the number of tests in which the top of the chimney reached the top of the volcanics and penetrated into the carbonates was information provided by the French authorities. Direct verification by drilling was neither feasible nor advisable as it would open new leakage paths. It was pointed out that the assumption of only a few percent of plutonium in the rubble was very conservative, as was subsequently confirmed by underground sampling. Basic properties of other elements, especially volatility, were used in order to estimate the partitioning between lava and rubble.[12]

Once the Conference was satisfied about the amount of radioactive material that remained underground, it went on to discuss the assessment of the migration of radioactive material through the geosphere.

This started with what for me was a very interesting tutorial on atoll geology.[13] The evolution of an atoll from a volcanic island was described. Over the period since their creation, the atolls have moved with the lithospheric plate some distance from the hot spots that created them. I believe that the Conference was convinced that there is no potential for renewed volcanism and that the seismicity in the region is now low. The volcanics and carbonate rocks forming the atolls are extensively fractured on various scales, so they behave from a modelling viewpoint as essentially isotropic. Slope failures occur naturally in the upper carbonate layer of such atolls.[14] The question was asked whether the sediments came from the lagoons; the bulk of them are attributed to erosion of the slopes.

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9 Op. cit., Table XXIX and Fig. 52.

10 Op. cit., sub-section 5.5 and Table XXV.

11 Op. cit., sub-sections 5.6 and 5.8.

12 Op. cit., sub-section 5.10.

13 Op. cit., sub-section 2.3.

14 Op. cit., sub-section 6.2.

A separate but related issue discussed by the Conference concerned the effect of underground nuclear tests on atoll stability. Even though an explosion caused a cavity and later a cavity-chimney with a fractured surrounding volume, the bulk strength of the rocks is essentially unchanged. Even two major tests carried out in close proximity resulted in only a small settlement at the surface. The Conference noted with interest that there remained a potential for slides, especially in the north-east area of Mururoa. Discussion at this point focused on the slide potential and future French monitoring, which was generally considered adequate.

An interesting description of the hydrogeological situation at the atolls followed.[15] The Conference learned that the main influence on the groundwater flow in an atoll in an undisturbed condition is buoyancy forces due to the geothermal flux heating the system from below. Cooler and denser ocean waters penetrate at depth from the atoll flanks and move upwards towards the lagoon. There is a freshwater lens from rainfall, but at Mururoa it is only a few metres thick and brackish. The groundwater velocities in the volcanic rocks are generally very low, whereas in the carbonates with karstic inclusions they are much higher. Independent calculations were made of permeabilities; the resultant temperature profiles and flow patterns were in good agreement with observations. Nuclear testing has changed the hydrogeological system in two ways:

- by creating zones of increased permeability around each test location, and
- by generating energy in situ, which results in a significant increase in temperature in the cavity-chimney (typically to 25-50 degrees celsius above ambient levels).

This temperature excess is not dependent on yield, and it will decline to negligible levels after a few hundred years. The main results from many calculations were the Darcy velocities between the top of the cavity-chimneys and the carbonates. It was suggested that, in a future ice age accompanied by a substantial drop - in excess of 100 metres - in sea level, the freshwater lens would become much larger and could intersect some of the safety trial locations.

The importance of verifying the overall model and the parameter values against the tritium data was emphasized in the discussion. The model was also robust against uncertainties in the relative horizontal and vertical permeabilities.

The Conference noted that the release of radionuclides into the water within the cavity-chimneys would be from two sources, the rubble - with concentrations in the chimney water determined by sorption equilibrium - and the lava, from which the radionuclides would be released very slowly.[16] Initially, the transport models were temperature-driven; later, for test

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15 Op. cit., sub-section 6.3.

16 Op. cit., sub-section 6.4.

chimneys and for safety trials, normal water flow was assumed, with dissolution at the solubility limit. Where possible, data from the Study or from the literature were used, and conservative parameters were generally chosen, but more realistic parameters were used where direct verification was possible - by measuring radionuclide concentrations in the cavity-chimneys from two tests. In discussion, it becomes clear that the Study's modelling would overestimate releases, especially for plutonium - as a result of the assumption that only 95% was in the lava.

The Conference now turned to the radionuclides released into the carbonate zone.[17] A dual porosity model, using the water velocities determined by the hydrogeological studies described in the previous session, was employed to estimate the rate of migration of material dissolved in the waters of the cavity-chimneys through the volcanics to the carbonate layers. The results of the modelling were presented to the Conference. Thirty-two radionuclides had been selected for consideration: tritium and the three nuclides of major radiological significance - namely, strontium-90, caesium-137 and plutonium; six non-sorbing nuclides; 14 short-lived sorbing nuclides; and eight long-lived sorbing nuclides. The results of the modelling were presented for each nuclide as a set of break-through curves showing the rate of release (in becquerels per annum) as a function of time over the next 10 000 years. The discussion centred around the apparent increase in the concentration of strontium-90 in the Mururoa lagoon observed in the aquatic sampling campaign - an increase inconsistent with the modelling, which predicted virtually no release of strontium-90 from the volcanics into the carbonates. It was suggested that too much reliance should not be placed on single measurements of single radionuclides. However, a possible source of the apparent increase in the strontium-90 concentration was the three safety trials that went critical, which were carried out in the carbonates.

The results of independent measurements carried out by the Study of the concentration of various radionuclides in the underground water of the atolls were reported to the Conference.[18] As well as samples from wells drilled into the carbonates, water was taken from the cavity-chimneys of two underground tests. The results were used in checking the calculations of the solution source term made by the Study. The samples taken from the test cavity-chimneys confirmed the extremely low levels of plutonium and other actinide elements in the cavity water, indicating the high degree of retention of these elements in the lava. Discussion focused on the very low levels of plutonium and americium found in the water of the two cavity-chimneys and the concentration of these nuclides assessed in the modelling done by the Study. The Study had clearly, and deliberately, assumed conservative values for the fraction of plutonium absorbed on rock surfaces and for the fraction of plutonium trapped in the lava. The evidence was that much more of the plutonium was trapped in the lava than the 95% assumed in the migration calculations. This observation of a very high fraction of plutonium trapped in the lava was expected to hold for all tests, independently of their yield.

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[17] Op. cit., sub-section 6.5.

[18] Op. cit., sub-sections 6.6.1 to 6.6.4.

A simple model to describe the release to the environment of radionuclides that have migrated to the carbonates was discussed.[19] They collect in the carbonate layer, from which a fraction will be released to the lagoons and a fraction direct to the ocean through the sides of the atolls. The results of this modelling were presented in terms of the change with time in the concentrations of the key radionuclides mentioned before, in the water of the lagoons, and in terms of the rate of release of these radionuclides direct to the ocean, also as a function of time. It was pointed out that, using conservative values for certain parameters, this model predicted that the rate of release of strontium-90 to the lagoons could increase over the next decade or so, which was consistent with the observations made during the Study sampling campaign. In my view, the Conference was not inclined to give much weight to the predicted increase in the rate of strontium-90 release to the lagoons as it was based on the very conservative - low -value assumed for the Kd of strontium in the carbonates.

The Conference discussed a number of hypothetical disruptive events that could possibly lead to an enhanced rate of release to the environment of radionuclides at present underground, or to enhanced levels of exposure.[20] It was noted that glaciation (assumed to occur in 50 000 years' time, with a 100 metre drop in sea level) could result in exposures due to residual plutonium in lagoon sediments and to the drinking of water from the freshwater lens that would form within the carbonates and which could possibly intersect one or more of the safety trial cavities. A scenario involving an assumed slide of carbonate rock at the northern rim of Mururoa Atoll, where it might intersect the cavity-chimney of a CRTV test and the cavity of a safety trial that did not go critical, was analysed in detail. To provide a "worst case scenario", it had been assumed that all the plutonium in the safety trial cavity would go immediately into solution and would be available for transport to neighbouring islands -- a very conservative assumption that was criticized by some participants as being unrealistic. The consequences of the slide were later discussed in the sessions on oceanographic modelling and on the assessment of the radiological situation.

A review of the oceanographic modelling was discussed. Models were used to simulate, assuming no changes in oceanographic conditions, the concentrations of the key radionuclides at sites in the South Pacific Ocean over the next 10 000 years - in the lagoons, within a thousand kilometres or so from the atolls, and in the far field extending to the coasts of South America and Australia. The near field modelling of flow in the lagoons was described.[21] It led to residence time and turnover time values for both lagoons. A related model was used in estimating the rate of removal of plutonium-containing sediments from Mururoa lagoon under normal conditions and during a major (one year in ten) tropical cyclone.

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19 Op. cit., sub-section 6.6.6.

20 Op. cit., section 7.

21 Op. cit., sub-section 8.3.

During the discussion, it was questioned whether the bottom sediment removal rate predicted by the sediment removal modelling was consistent with assumptions about sediment accumulation rates made elsewhere in the Study. Two points were made during the discussion. The concentration values for the key radionuclides found in the ocean are for the most part extremely low, and very much lower than existing concentrations due to global fallout. Subsequently, it was pointed out that it would be difficult for laymen to appreciate the significance of concentrations of microbecquerels per cubic metre and the like. One microbecquerel per cubic metre is the equivalent of one disintegration every million seconds in one cubic metre of water. This enters the range where statistical fluctuations in count rate become very significant.

There was also some discussion on "worst case scenarios". It was argued, for example, that the assumption in the rock slide scenario that all the plutonium goes instantly into solution was scientifically not credible. It was suggested that conservatism in the assumptions leading to this source term had been taken so far that the concentrations calculated for Tureia as a consequence of the rock slide were not plausible.

The three compartment models used in simulating concentrations within a thousand kilometres or so of the atolls (the intermediate region) resulting from instantaneous and time-dependent releases were described.[22] An advantage of compartment models is that they can cover long time periods without excessive use of computer time; however, because of the spatial and temporal averaging that is inherent in compartment modelling, the resolution is often not high. Wherever possible, independent - verified and conservative - oceanographic data were used. The use of three models allowed intercomparison of results where the models overlapped. In general there was agreement within an order of magnitude in predicted concentrations.

The results of far field modelling were illustrated in a number of figures showing concentrations throughout the South Pacific of key radionuclides - particularly tritium and plutonium - resulting from instantaneous and time-dependent releases into the surface layer of the ocean and at depth, below the thermocline.[23] Because of the very large amount of computing time required in order to run the model, migration was followed for only a few decades. A feature of the model is the prediction that surface releases will initially move in an easterly direction, with some migration towards the west due to dispersion. Releases at depth will move towards the west, with less initial dilution than for surface releases. All increases in concentration rapidly become very small - orders of magnitude below existing background concentrations due to global fallout. In the discussion, it was noted that the far field simulations result in extremely small radionuclide concentration elevations a thousand kilometres or so from the atolls. It was again emphasized that concentrations of microbecquerels per cubic metre are "virtual concentrations"; concentration elevations of this

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22 Op. cit., sub-section 8.5.3.

23 Op. cit., sub-section 8.5.4.

size are orders of magnitude less than existing background concentrations in the open ocean due to global fallout and would be unmeasurable. Let me emphasize what these background concentrations are: for tritium about 100-200 Bq/m3; for strontium-90 and caesium-137 about 2 Bq/m3; and for plutonium about 3 mBq/m3.

In the last group of technical sessions, the Conference addressed other issues related to its main topic. First, the proposals of the French Government for long-term monitoring at the atolls were discussed.[24] The Conference noted that radiological and geomechanical monitoring has been carried out at the atolls for more than 30 years. On the basis of the Study, it was concluded that no further environmental monitoring is needed at the atolls for the purposes of radiological protection. The radiological programme will be similar to that carried out over the past decade or so, but at a somewhat reduced level. A sampling campaign at the atolls will take place once a year. It was noted that a scientific programme of monitoring of the radionuclide concentrations in the carbonate formations and in the nuclear test cavity-chimneys will continue. The Study recommends that emphasis be placed on monitoring the migration behaviour of long-lived and relatively mobile radionuclides and radiocolloids because of their particular scientific interest. There will be geomechanical monitoring of the stability of the northern part of Mururoa and of the flanks of both atolls - monitoring by a permanent system, with automatic satellite transmission of results, and on-site inspections every 3-10 years. The Conference noted that the scientific programme, supplemented by some monitoring of radionuclide levels in the biosphere, may also be useful in assuring the public about the continuing radiological safety of the atolls. It is expected that the monitoring results will be published on an annual basis.

Then, the Conference took note of the assessed effects on species other than man.[25] The Study had assessed the dose rates to native biota resulting from the residual radioactive material at the atolls and, in the great majority of cases, had found them to be similar to or lower than dose rates due to natural radiation sources. It was assumed that radiation doses are distributed over the whole body of the animal with no differentiation between organs, but account was taken of different water, tissue and sediment pathways, and of low- and high-LET radiation separately. Benthic crustacea in the lagoons receive the highest exposures from ambient concentrations of radioactive material. Potentially high dose rates could be experienced by individual members of some species owing to plutonium contained in "hot particles" in the Colette sandbank. It was suggested that the question of damage to gonad tissue in small animals might be studied for scientific purposes. The possibility of many hot particles being concentrated in larger fish and eaten by man was considered to represent no real risk because of the combination of low probability of intake by fish, low human

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[24] Op. cit., sub-section 4.1.3, and French Liaison Office document No. 12 (Ministère de la défense, Direction des Centres d'expérimentations nucléaires et Commissariat à l'énergie atomique, Direction des applications militaires, Vol. 1, *Guide de surveillance géomécanique des atolls de Mururoa et Fangataufa*; Vol. 2., *Guide de surveillance radiologique des sites de Mururoa et de Fangataufa*, June 1997).

[25] Op. cit., section 10.

consumption of the gut contents of fish, and a very low human gut uptake factor. Overall, the Study concluded that the expected radiation dose rates and modes of exposure are such that no effects on biota population groups could arise, although occasionally individual members of a species might be harmed, but not to the extent of endangering the whole species or creating imbalance between species.

Finally, an issue which is rather esoteric as far as this Conference is concerned but which interests me professionally very much, was discussed: CIGUATERA.[26] Ciguatera is a type of food poisoning which people contract by eating fish contaminated with a toxin generated by a marine micro-organism often found in association with disturbed coral reefs. There have been some reports in news media that outbreaks of ciguatera may be linked to exposure to radiation from the residual radioactive contamination at the atolls. The symptoms of ciguatera poisoning were recognized long before the start of the nuclear test programme (over a century ago, in fact), and a range of anthropogenic and natural disturbances may contribute to abrupt ciguatera outbreaks. At present, there is no known medical treatment. A question was asked about whether Ciguatera could be transmitted through the placenta, resulting in the birth of deformed children. No evidence exists to resolve this issue. However, there is certainly no evidence in the scientific literature of radiation exposure being a causal factor for outbreaks of ciguatera.

And thus, the Conference moved on to the technical sessions on assessments.[27] The Conference learned of the final assessment of the present and long-term radiological situation. Mururoa Atoll has been inhabited only occasionally in the past, and there is no evidence that Fangataufa has ever been inhabited. The lack of a water supply and the vulnerability of the atolls to the sea make it difficult for people to live there. However, for the purposes of the Study the existence of a hypothetical population resident on Mururoa was assumed in order to determine potential radiation doses. Also, the estimation of doses to more distant communities was necessary in order to establish the significance of any releases of radioactive materials to the ocean. Account was taken of radionuclides migrating from underground and remaining from the atmospheric tests and of radionuclides that might be released as a result of disruptive events, such as a landslide, or of changes in climatic conditions. The dose assessments undertaken for the purposes of the Study were described after a brief introduction to the methods used for dose calculations. The conclusion of the assessment is that the calculated annual doses due to the dispersion of radionuclides from the French nuclear testing programme at Mururoa and Fangataufa Atolls are all very small when compared with annual doses from natural background sources; the corresponding health impact is similarly insignificant. Overall, the radiation risks to current and future generations from the French nuclear testing programme at Mururoa and Fangataufa are so small that they can be considered to be negligible.

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26 Op. cit., Annex II.

27 Op. cit., section 9.

In response to questions raised about the hypothetical radiation doses from seafood consumption, it was stated that the transfer parameters used were based largely on the results of an international study (the MARDOS Study) and that the dietary information was taken from published literature on consumption patterns at Tureia. Assumptions made with regard to the impact of future climate changes were questioned, particularly those concerning the effects that might be caused by glaciation. For example, relatively minor lowering of the sea level (by perhaps 10-15 metres) could presumably occur during inter-glacial periods well before 50 000 years. The consequences of such alternative scenarios did not appear to have been taken into account in the Study. In response, it was stated that the assumptions made as to when glaciation will occur in the future would have little effect on the resulting assessed radiation doses. Lowering of the sea level by 10-15 metres would expose only small areas of the lagoon bottom near the present coral rim.

Given the results of all the technical sessions, I submit that it is obvious to all of us that there is no need for radiation protection remediation at Mururoa and Fangataufa. However, the criteria for remediation were discussed by the Conference.[28] In my view, this is good because, as we noted before, the Agency has been involved in a number of radiological assessments where the need for remediation was in fact demonstrated. The Conference noted that there is currently no explicit international guidance on generic action levels for chronic exposure due to radioactive residues from previous activities and events, such as nuclear weapon testing. The guidance established in the International Basic Safety Standards for other situations has been used in providing indications of the levels that might be appropriate. In addition, typical levels of doses caused by chronic exposure to the unavoidable natural background radiation have been used as a reference for comparison. On the basis of these considerations, it appears that intervention in chronic exposure situations is unlikely to be warranted in order to achieve a reduction in annual effective dose to levels of less than about 10 mSv. A dose in the region of 10 mSv therefore appears to be a reasonable generic guideline for intervention.

I believe that the Conference was glad to learn about the many developments that are taking place in this area of basic radiation protection criteria, both within the International Commission on Radiological Protection and within the International Atomic Energy Agency. I conclude that we should encourage these two organizations to continue to steer towards simple criteria for dealing with radioactive residues from the past. Such criteria will have to be used in many places around the world where there is a legacy of radioactive residues from the past, particularly from military activities.

So we arrived at the findings, conclusions and recommendation of the Study, which have just been so brilliantly presented by the Chairman of the International Advisory Committee, Dr. de Planque. I would request the Agency's Secretariat to ensure that the

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[28] Op. cit., section 11.

findings, conclusions and recommendation and the discussion which took place a few minutes ago are brought to the attention of the Agency's General Conference.[29]

I understand that the Chairman of the International Advisory Committee, Dr. Gail de Planque, and the Director General of the Agency, Dr. Mohamed ElBaradei, wish to address us at this point. I give the floor first to Dr. de Planque and then to Dr. ElBaradei.

Closing remarks by Gail de Planque
Chairman of the International Advisory Committee

I would like to take a moment at this point to thank all the Study participants for a job well done. I hope that the Study has added to the fundamental knowledge base of science and technology. I also hope that it will help our societies to face technical challenges such as the designing and constructing of safe facilities for the disposal of radioactive waste.

From the scientific point of view, the Study was for me a wonderful opportunity to learn a lot about many areas of which I knew very little. I hope that all the Study participants learned as much as I did. At the personal level, I find that such exercises provide an opportunity to acquire many new friends for life. I think I acquired new friends for life, and I hope the other Study participants did also.

As to the Conference, I would like to thank you all; you made this a very successful four days. The questions asked and comments made were very perceptive, and the discussions were very useful.

I wish to single out two Conference participants for special thanks: Mr. Shorten from the South Pacific Forum and Mr. Carroll from Greenpeace International. We had hoped to have more representatives of the South Pacific Forum here, but that was not possible. The interests of the people of the South Pacific region were very much in our minds during the Study, and in May a small group of us visited the region in order to present the Study results there. I hope Mr. Shorten will convey the conclusions of this Conference to the people of the South Pacific region. I am very pleased that Mr. Carroll was able to be with us. I thank him for the complimentary statements that he made, but even more for sharing his thoughts with us. I believe that essentially we all have the same basic goal, the protection of our planet and its inhabitants, and that improved communications among the various groups around the world will help us all in achieving that goal.

Turning to the IAEA, I should first like to thank Director General ElBaradei for his encouragement and support and for making the necessary IAEA resources available for the

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[29] The findings, conclusions and recommendation of the Study are set forth in the Executive Summary contained in Attachment 1 above. The discussion which took place immediately before the President's "Conclusions and Closing Remarks" are summarized in the Annex hereto.

Study. The IAEA staff involved in the Study - and there were many of them - contributed enormously; the Study would not have been successful without their efforts. Unfortunately, time prevents me from naming them all, but there are three whom I should like to single out: Abel González, the Project Manager; Bob Fry, the Technical Project Manager; and Renate Boldizsar, the Administrative Assistant.

I have always had the greatest respect for Abel González's scientific expertise and managerial talents, but on this occasion Abel absolutely outdid himself, eliciting an extraordinary effort in an unbelievable amount of time. It was a delight to work with him.

Bob Fry came to Vienna from Australia innocently thinking that he was going to spend six months here in connection with the Study; he has been here for the past year and a half. He has laboured untiringly behind the scenes, often under-appreciated, putting together a comprehensive scientific patchwork quilt and making possible the production of all the Study documents. Bob deserves the gratitude of us all.

Renate Boldizsar has been absolutely amazing, bringing people together from all parts of the world and keeping them happy. I am sure she has many fascinating stories to tell. Thank you, Renate!

I thank the French Government for requesting the Study; it has set a fine example for others. I also thank our French colleagues for their openness and co-operation throughout the Study; it was a marvellous experience. In particular, I would mention Mr. Sornein and Col. Corion, who were extremely patient and shared their expertise with us as we struggled to understand the technical aspects of a programme with which they were very familiar.

I thank Dr. Bobadilla López, who has done an excellent job in chairing the Conference, and I hope that I can count him among the new friends acquired through the Study.

In summary, it has been a pleasure and a privilege to work with all of you. I found the Study and the Conference a rewarding and enriching experience, both professionally and personally. I hope that our paths cross again many times. When Abel González feels that an issue has been resolved, that there is nothing more to be done, he often concludes with "Punto, finito!". So I say: "Punto, finito!" and thank you all.

Closing remarks by Mohamed ElBaradei,
Director General of the
International Atomic Energy Agency

It is a pleasure for me to address you today.

I have just returned from visiting the Middle East where, among other matters, I addressed a Conference on Emerging Nuclear Energy Systems. My message there is equally relevant here:

Since its very beginnings, atomic energy has carried hopes and apprehensions. The hopes - for a safe, environmentally friendly, cost efficient and virtually unlimited source of energy used for exclusively peaceful purposes for the benefit of humanity - are even more relevant today to help mitigate global climate change and to meet the growing energy demand that is essential for developing countries.

The apprehensions - that atomic energy may be used unsafely or for destructive purposes - have been underscored by a number of events, notably the Chernobyl accident and Iraq's clandestine weapons programme, which cast a shadow in the public mind on the peaceful utilization of nuclear energy.

The IAEA was established over 40 years ago precisely to help bring to fruition the hopes for atomic energy and to assist in curbing the apprehensions. Through five inter-related tasks, the Agency has sought to contribute to the beneficial, safe and peaceful uses of atomic energy.

To assist in realizing the hopes, the Agency's tasks are:

- to act as a catalyst for the scientific community and as a hub for state-of-the-art technology;

- to act as a centre for the transfer of nuclear technologies so as to ensure their accessibility to Member States in general, and to developing countries in particular; and,

- to assist Member States to make informed and appropriate choices concerning the energy mix by conducting comparative assessments of nuclear and other technologies.

To help curb the apprehensions, the Agency's role is:

- to assure, through its verification system, that pledges to use nuclear energy exclusively for peaceful purposes are fulfilled - that is, the role of "nuclear watchdog"; and

- to strive for the highest level of safety in all areas of the use of nuclear energy.

In the area of verification, through its safeguards system, the Agency seeks to assure that pledges to use nuclear energy exclusively for peaceful purposes are fulfilled. In 1997, over 180 States were subject to IAEA comprehensive safeguards. Safeguards were applied to over 900 facilities involving more than 10,000 days of inspection.

The experiences this decade in Iraq, in the DPRK and in the very different case of South Africa led the international community to show the political will to enable the IAEA to

develop a more effective strengthened safeguards system that is designed to provide assurance not only about nuclear activities declared by a State, but also about the absence of undeclared activities. Very good progress is being made by States in concluding the legal instruments necessary for implementing the new measures.

Most recently, Russia, the United States and the IAEA are examining arrangements for the Agency to verify that fissile materials removed from dismantled nuclear weapons or excess to defence programmes are not returned to weapons use or diverted. This undertaking would be the first specific mission for the IAEA in the international verification of steps towards nuclear disarmament, in relation to the obligations of Article VI of the NPT.

While the responsibility for nuclear safety lies primarily with national Governments, the IAEA plays a fundamental role through three complementary activities: the development of legally binding international agreements and the servicing of their implementation; the establishment of a comprehensive corpus of non-binding safety standards; and the provision of assistance in the application of those standards through activities which include safety services, training, fostering scientific research, technical co-operation and information exchange.

The purpose of this conference has been to present for peer and public review the results of this major and impressive Study directed by an International Advisory Committee of distinguished scientists, convened by the IAEA, to examine the present and future radiological conditions at the two South Pacific atolls following three decades of atmospheric and underground nuclear weapons tests by France.

The Study is one of a series that the Agency has undertaken, at the request of Member States, to assess present and future radiological conditions and possible hazards at former nuclear test sites and, if affected areas are to be populated or otherwise put to human use, to make recommendations on any remedial actions needed.

The role of the Agency in undertaking these studies and, indeed, throughout all our activities, is to be objective and scientifically credible. Hence, we welcome and encourage scientific review of the methodologies, conclusions and recommendations of this Study.

The IAEA General Conference has called on all relevant States "to fulfil their responsibilities to ensure that sites where nuclear tests have been conducted are monitored scrupulously and to take appropriate steps to avoid adverse impacts on health, safety and the environment as a consequence of such nuclear testing". The Agency remains prepared to respond to further requests in this area. As noted by Dr. Bobadilla, the news from the other two studies in the Bikini Atoll and Semipalatinsk are not the same as the ones that have emerged from this Study. But I concur with him that bad news could be converted into good news if appropriate remedial actions are taken with appropriate resources made available to the Agency.

The conclusions of this particular Study should provide welcome assurance to the people of the South Pacific region. But these conclusions in no way condone nuclear testing. Limiting the environmental impact of testing is not the answer to global and regional apprehensions. The objective of the international community must be to eliminate entirely nuclear weapons and nuclear weapons tests. The cold war has left a legacy which should remain a legacy. A nuclear club with five members too many.

It remains for me to reiterate the Agency's gratitude to the many experts from some twenty States and six intergovernmental organizations who participated in the conduct of the Study. In particular, I wish to thank you, Mr. Chairman, and the members of the International Advisory Committee and its able chairperson, Dr. Gail de Planque, for the dedication, energy and expertise in guiding this major Study to its conclusion. I would like also to express appreciation for the outstanding work by the many Agency personnel, both in Headquarters and in its laboratories, and to note in particular the meritorious achievements of Drs Abel Gonzalez and Robert Fry.

Finally, I would ask the representative of the Government of France at this Conference, the former Minister of Research and Technology, Mr. Hubert Curien, to convey to the French Government the Agency's appreciation for its openness in sharing information and for its substantial support in the conduct of the Study - a fine example to be followed.

Closing remarks by Eduardo Bobadilla López,
President of the Conference

Thank you Dr. de Planque and Dr. ElBaradei.

Let me now close this Conference with some personal remarks. First, allow me to say that it was an enormous pleasure for me to participate in this Conference with all of you. The presentations and the discussions have introduced me to a number of scientific subjects which were unknown to me and remote from my professional background. During the Conference, I enjoyed the elegance of the presentations and the solidity of the foundations on which the Study conclusions are based. The robustness of the conclusions derives from the strict scientific criteria applied by the International Advisory Committee, from the critical analysis of the data provided by the French authorities and from the consistent adoption of conservative hypotheses throughout the Study. The calibre of the researchers and the institutions involved, which could be taken for granted, was important for the conclusions of the Study.

The results of the Conference may be summarized as follows: "there will be no radiation health effects which could be medically diagnosed in an individual or epidemiologically discerned in a group of people" and "the expected radiation dose rates and modes of exposure are such that no effects on biota population groups could arise".

These simple statements will probably be called into question by the general public and the media. Wide diffusion of the Study reports should therefore be recommended by all of us - by the representatives of 42 countries and eight organizations who took part in the Conference and by the observers from 12 institutions - and, of course, by the Agency.

The Study will gain additional credibility if its results are not used for justifying the development and testing of nuclear weapons. In my view, the development and testing of nuclear weapons should be rejected because, even if the radiation impact on human beings and on biota is negligible, international security and ethics must prevail over all other considerations. Rather, we should use the Study's results in promoting the general advancement of science and in dealing with the greatest problem of nuclear power development - the safe disposal of high-level radioactive waste.

In conclusion, I would like to express my gratitude to Dr. Gail de Planque for the manner in which she chaired the International Advisory Committee and for the role which she played during the Conference. Also, I would like to thank the Agency's Secretariat - especially Dr. Abel González - for courageously inviting me to chair the Conference. In addition, I would like to thank all of you, the Conference participants, who made the Conference so meaningful. Lastly, on your behalf, I thank the interpreters and the Conference Services staff of the Agency.

I declare the International Conference on the Radiological Situation at the Atolls of Mururoa and Fangataufa closed.

SESSION 15[1]: DISCUSSION

(Discussion panel: G. de Planque, Chairman of the International Advisory Committee, United States of America; D.M. Levins, Australia; and A. McEwan, New Zealand)

G. de PLANQUE (United States of America): I should like to ask a question. Seeing the results of the Study, how do you think one should go about planning and conducting similar studies in the future?

P.R. DANESI (IAEA): I am not the best person to respond to that question, but I should like to say a few words about the possibility of similar studies being conducted in the future.

The results of the Study are more reassuring than most of us thought they would be when we embarked upon it. I hope that this fact will be a stimulus as regards the launching of radiological studies of other former nuclear test sites.

The launching of such studies will depend on decisions taken by States at the political level. As far as the Agency's Secretariat is concerned, I am sure that it would be ready to participate if the necessary resources were made available.

S. CARROLL (Greenpeace International): I think the Study could serve as a model for similar studies of former nuclear test sites. There are some sites - like the Semipalatinsk one - where we have a fairly good general idea of what to expect, but there are some about which we know nothing, or next to nothing, and I would urge the States within whose territories these sites are located to open them up to international scrutiny the way France finally decided to do.

I should like to make two critical comments here which should not be taken as criticisms of the manner in which the Study was conducted.

Firstly, it would have been useful if the reports available at this Conference (the Main Report, the six Technical Reports and the Summary Report) had all been made available sufficiently ahead of the Conference for us to examine them properly. In my view, they should ideally have been issued before the results of the Study were presented, in May, to

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[1] See footnote 29 on page 16 of Attachment 3 to document GC(42)/INF/3

representatives of the governments of member States of the South Pacific Forum and representatives of French Polynesia.

Secondly, I think it should have been made clearer in the documentation what the Study did not look into and which data were not validated by the Study.

That having been said, I congratulate the Study participants on a marvellous effort and thank France for making so much information available - as Greenpeace had been urging it to do for more than 20 years.

D.M. LEVINS (Australia): Dr. Danesi just said that the results of the Study were more reassuring than expected by most. In that connection I would mention that I was recently asked by a newspaper representative whether, in my view, those results indicated good luck or good planning on the part of the French. In response, I said basically that in my view the French made a few mistakes - particularly in connection with the safety trials - but resolved the resulting problems and learned the necessary lessons. One can only hope that those who have carried out nuclear tests at other sites learned from whatever mistakes they made.

M. TSCHURLOVITS (Austria): It has been stated that the conclusions of the Study are very robust. Nevertheless, I should be interested in knowing the uncertainties associated with the various conclusions.

A.C. McEWAN (New Zealand): The conclusions arise out of the doses which have been calculated. In the case of the calculated doses to a current hypothetical population, we consider the values to be correct to within a factor of two. In the case of future doses, the uncertainties are much greater. For example, the values obtained by assuming that all the plutonium would go into solution in the event of a rockslide could be too high by a factor of 100 or more.

D.M. LEVINS (Australia): I would point out that, even with the conservative assumptions made in order to be sure of obtaining maximum calculated dose rates, the dose rates which we calculated are several orders of magnitude below the level of significance.

G. de PLANQUE (United States of America): There were uncertainties due to the dose calculations and uncertainties due to the modelling. We did not sum them, but even together they are not radiologically significant and therefore would not affect our conclusions.

G. SHORTEN (South Pacific Forum): I should like to commend the International Advisory Committee and the other people involved in the Study for two years of intense work done in a very professional and open manner. At the same time, I hope that, before being

issued in their final versions, the various reports will be adjusted so that people like me can tell those to whom we are responsible that the Study covered everything of significance.

If someone had told me, at the start of the programme of French nuclear tests at Mururoa and Fangataufa, that after completion of the programme it would be safe to "eat the sands" of the atolls, I would not have believed that person. Now the Study has shown that the site is clean, but an act of faith will be required of the South Pacific Forum and those whom it serves. I hope that I shall receive help in getting the message across.

G. de PLANQUE (United States of America): I am sorry that there are not more representatives of the South Pacific Forum present at this Conference.

On the other hand, I am not sorry that we did not have the final versions of the various reports available when we visited the South Pacific region in May to present the results of the Study to representatives of the governments of member States of the South Pacific Forum and representatives of French Polynesia - or that we have not had the final versions available at this Conference. The reason why I am not sorry is that the discussions this week have convinced me that certain clarificatory adjustments could usefully be made before the final versions go to press.

E. BOBADILLA LÓPEZ (Chile, President of the Conference): I would be interested in knowing the opinion of panel members regarding the use of knowledge gained through the Study in the design of high-level radioactive waste repositories.

D.M. LEVINS (Australia): The amounts of fission products underground at Mururoa are very low - equivalent to the amounts produced during seven weeks of operation of a 1000 MW(e) power reactor. Nevertheless, the atoll is an excellent "laboratory" for studying the fate of radionuclides in the environment - albeit an unusual environment. I am therefore glad that the French are going to continue monitoring at the atoll.

The nuclides of greatest interest in the high-level waste context will be not so much radioactive forms of caesium and strontium, against which repositories can be provided with engineered barriers that will survive a long time, as very long-lived radionuclides like technetium-99 and neptunium-237.

G. de PLANQUE (United States of America): In that connection I would recall that the International Advisory Committee concluded that no further environmental monitoring at Mururoa and Fangataufa is needed for purposes of radiological protection and, at the same time, recommended that the emphasis in any future monitoring be placed on the migration behaviour of long-lived and relatively mobile radionuclides and radiocolloids because of its particular scientific interest.

G. SHORTEN (South Pacific Forum): I believe the people of the South Pacific region will be pleased about France's plans for continued monitoring at Mururoa and Fangataufa.

S. CARROLL (Greenpeace International): I accept that the radiation doses at the atolls are low and I believe that continued monitoring there is essential, but hope no one is thinking of using either atoll as a radioactive waste dump.

G. de PLANQUE (United States of America): We members of the International Advisory Committee would certainly not endorse the idea of using the atolls for that purpose. We had in mind the use of knowledge gained through the Study about - for example - radionuclide transport through various geological media and various types of water body - in the design of repositories to be built elsewhere.

C. FAIRHURST (United States of America): The radionuclides now present underground at the atolls have been immobilized by the nuclear explosions which gave rise to them in a manner different from the manner in which radionuclides are - or would be - immobilized in a repository, so the analogy between underground nuclear test sites and high-level radioactive waste repositories should be treated with care.

D.K. SMITH (United States of America): I think the Study has produced a unique set of scientific data which will be useful in studying both radionuclide migration underground at other nuclear test sites and proposals for the construction of high-level radioactive waste repositories.